Fermilab Directorate

MEMORANDUM OF UNDERSTANDING
FOR THE 2004-2005 TEST BEAM PROGRAM

T945

The Chicagoland Observatory for Underground Particle Physics (COUPP)

January 12, 2004

INTRODUCTION

This proposal requests space in the MINOS near detector hall to test a prototype heavy liquid bubble chamber. The COUPP (Chicagoland Observatory for Underground Particle Physics) collaboration has been working on possibilities for a next generation dark matter experiment with the capability to be scaled up to the >1 ton scale. Our feeling is that one of the most promising technologies is a static heavy liquid bubble chamber in which the target material for dark matter interactions is a superheated fluid. The power of this detector technology arises from its ability to discriminate between the nuclear recoil events expected from dark matter interactions and the much more common electron recoil events expected from backgrounds due to natural radioactivity. It is excellent gamma-neutron discrimination which provides the crucial strength of the CDMS experiment. In the CDMS detectors, this discrimination comes from the difference in ionization between the two classes of events. In the bubble chamber, it is the spatially compact nature of the nuclear recoil events which provides the discrimination. It is possible, by a judicious choice of operating pressure and temperature, to attain sensitivities for recoiling nuclei of a few keV while being completely blind to minimum ionizing particles such as photoelectrons. This is due to a threshold not only on the minimum energy that a particle must deposit, but also on the stopping power that it must have, if it is to nucleate a bubble. In a small (20 gram) device, we have already demonstrated gamma/neutron separation some 5 orders of magnitude better than CDMS.

The operating fluid we have selected is CF3I. This fluid has a long list of virtues and very few drawbacks. It is non-flammable (conventional halon is CF3-Br, CF3-I is marketed as an environmentally friendly substitute which has similar fire suppressant properties but without adversely affecting the ozone). It is non toxic. Its properties are such that it operates in a bubble chamber near room temperature and near atmospheric pressure. From the physics perspective the large atomic number of Iodine is highly desirable if the dark matter turns out to have spin-independent interactions which are enhanced like A^2. If dark matter interactions turn out to be spin-dependent, then the Fluorine will provide excellent sensitivity. The drawback is that CF3I is photosensitive and must be protected from exposure to UV light. Red LEDs are used to illuminate the bubble chamber for photography. Jim Priest has reviewed the issue of CF3I photodissociation and has determined that there will be no significant production of HF.

The device we would like to bring to Fermilab is a 1-liter prototype consisting of a quartz vessel housed inside a stainless steel pressure vessel. The quartz vessel holds the sensitive fluid and is attached by a flexible bellows to the top flange of the tank. The quartz vessel and bellows form a closed, clean volume. The space above the CF3I is filled with water. The quartz vessel is suspended from its bellows inside the outer pressure vessel. The outer pressure vessel is filled with roughly 20 liters of polypropylene glycol which serves as a compression fluid. A piston is used to compress the glycol which in turn compressed the CF3I. The virtues of this design are that the sensitive fluid is only in contact with the clean inner volume of the quartz and bellows, and that there is never any significant static differential pressure across the quartz. The nominal operating pressure of the system is 200 psi (compressed) and 15 psi (decompressed). The vessel is code stamped and rated to 600 psi. The apparatus is entirely contained in a three foot square 5 foot high support frame. The weight of the pressure vessel, support frame, and fluids is of order one ton. The apparatus is shown below in figure 1. Figure 2 is a close up view through a camera port showing the inner quartz vessel.

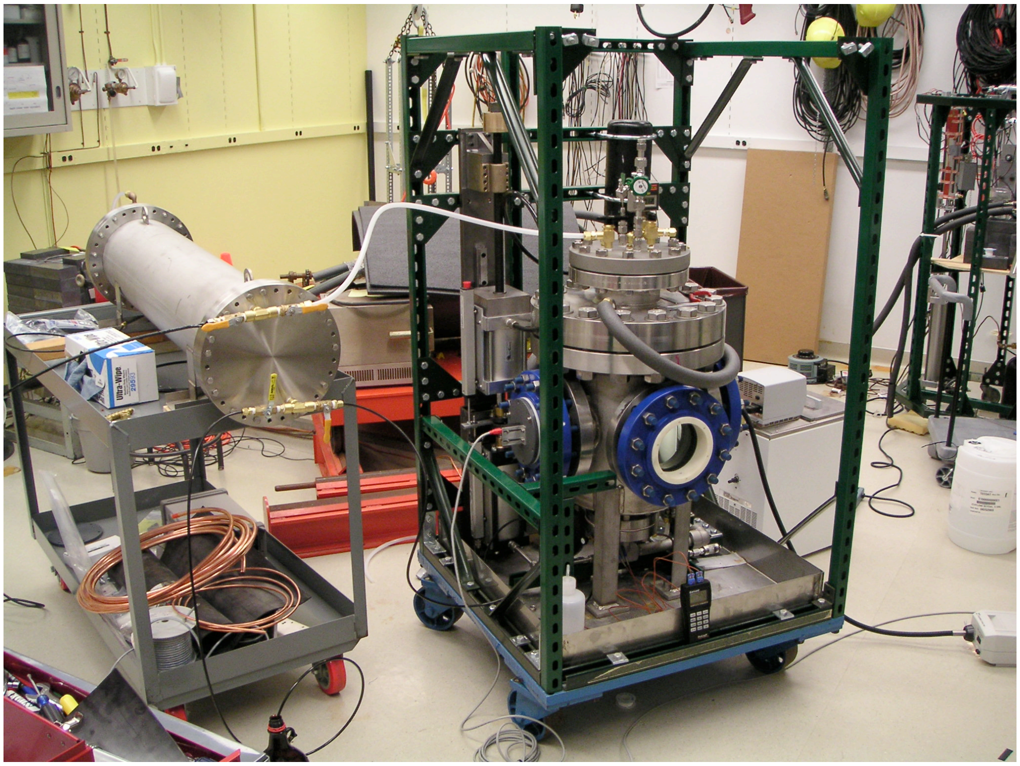

Figure 1: The COUPP 1-liter bubble chamber pressure vessel fully instrumented in its stand.

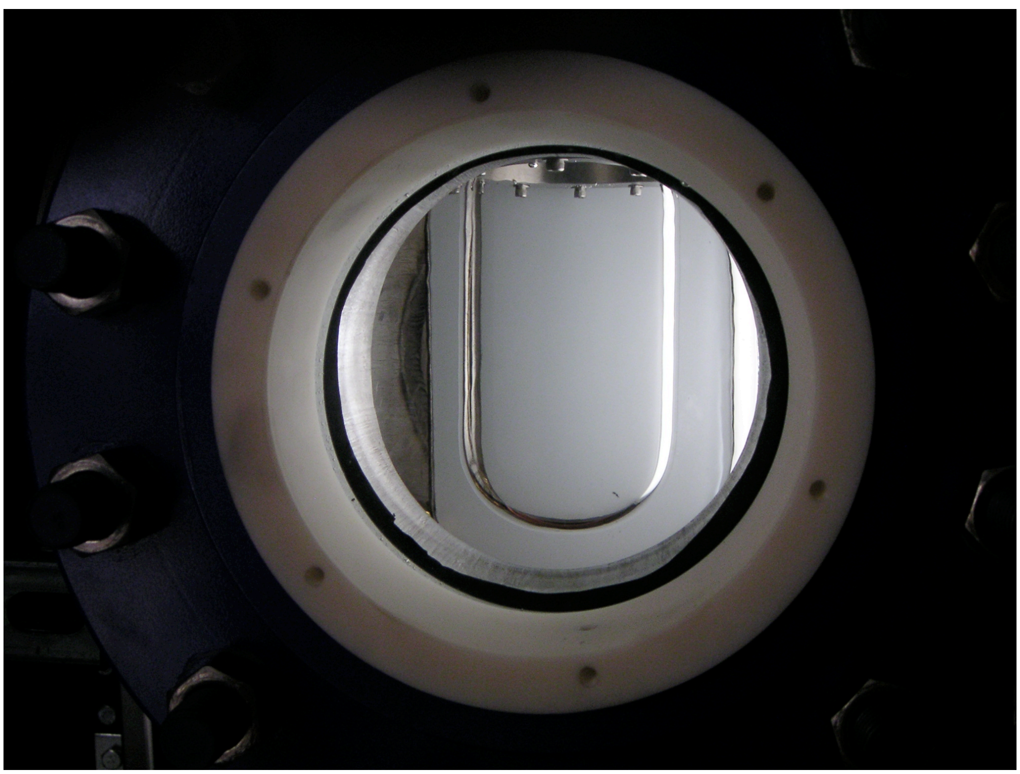

Figure 2: A view of the inner quartz bubble chamber vessel as seen through the camera port.

We have operated the device successfully at the University of Chicago at a depth of 6 m.w.e. and demonstrated an average superheated lifetime of about 60 seconds in conditions optimal for a WIMP search. This is consistent with the measured neutron flux in the lab at Chicago. We will continue to study our data and operate the chamber through December and will also add some polyethylene shielding which we expect to reduce the external neutron flux. We are very excited about the performance of the device so far, and we feel that the obvious next test is to transport the device to the deeper site in the MINOS near detector hall where we can check for the expected reduction in neutron interactions and see if we attain the expected increase in superheated lifetime.

Once we complete our characterization of the chamber in Chicago, we will drain it, clean it, make some small repairs, and refill it with glycol in the pressure vessel and water in the inner vessel. In our initial planning we had considered the possibility of transferring the CF3I in Chicago and then transporting the chamber under pressure so that we could do a precise comparison between the Chicago and MINOS event rates. While this would have been desirable from a physics perspective, we have been persuaded that it is not possible to safely transport the vessel when it is pressurized, and our chamber is not a DOT rated vessel. We are however concerned about the possibility of introducing contamination during the CF3I fill. Our plan is to attach all of the CF3I plumbing in the clean room in Chicago, but will keep the CF3I in its DOT rated vessel until the apparatus is in place at Fermilab. Once the chamber is securely in place in the MINOS hall (and once we have obtained all of the necessary approvals) we will transfer the CF3I into the inner vessel and pressurize the chamber.

We understand that this test will require an engineering/safety approval of the pressure vessel, a safety approval for the use of CF3I in the MINOS area, written procedures for handling, filling, and operating the chamber, and JHAs detailing how the device will be transported, lowered into the MINOS area, and rigged into place. An Operational Readiness Clearance will be obtained prior to pressurizing the chamber or operating it unattended. While we are convinced that the apparatus presents no hazard to personnel in the area, we imagine that the immediate vicinity of the chamber will be cordoned off once the device is installed. The Particle Physics Division will coordinate access to the MINOS tunnel. Once we have established the baseline count rate of the chamber in MINOS, our plan is to add roughly one foot of polyethylene shielding around the apparatus to further attenuate the neutron flux.

I. PERSONNEL AND INSTITUTIONS:

Scientific spokesperson: Juan I. Collar, Enrico Fermi Institute

Physicist in charge of beam tests: Andrew Sonnenschein, Kavli Institute

Fermilab liaison: Michael Crisler

The group members at present and others interested in the testbeam are:

1.1 Kavli Institute: J.I. Collar, J. Hall, D. Nakazawa, B. Odom, K. O'Sullivan, A. Raskin, A. Sonnenschein, J. Vieira.

Other commitments:
CERN Axion Solar Telescope: J.I. Collar

1.2 Fermilab: M. Crisler, D. Holmgren, R. Plunkett, E. Ramberg.

Other commitments:
CDMS: M. Crisler, D. Holmgren, E. Ramberg
MINOS: R. Plunkett

II. EXPERIMENTAL AREA, BEAMS AND SCHEDULE CONSIDERATIONS

2.1 LOCATION

2.1.1 The test is to take place in the MINOS near detector hall. There is a large area immediately upstream from the MINOS near detector which was heavily used for rigging and staging during the near detector installation. Now that the installation is complete, this area is largely unused except for the storage of some of the lifting and handling fixtures. Much of this area is well off the beam axis and would be ideal for the COUPP test. Our apparatus plus shielding will occupy a footprint roughly five feet square. A photo of the proposed site is included as APPENDIX II.

2.1.2 Additional work space will be needed nearby, equivalent to at most two 6'x3' tables. This space will be used for computing and general work space.

2.1.3 It there are concerns about space conflict with MINOS activities, it would be possible to mount the entire COUPP apparatus, including shielding, on a cart.

2.1.4 The apparatus requires two 110 V, 20 AMP circuits. One circuit will power the computer plus a few laboratory instruments. The second circuit is for a Neslab circulating heater/chiller unit which controls the temperature of the apparatus. The Neslab unit draws up to 16 amps and should have a separate circuit.

2.1.5 Access to a computer network connection will be necessary.

2.1.6 Access to a copy of the beam timing signal will be necessary.

2.2 BEAM

2.2.1 The COUPP test does not utilize any particle beams.

2.2.2 Because of our location well off the beam axis, we are reasonably confident that we will be able to work when the beam is running. We will certainly be able to work during the period before the NUMI beam is turned on and during any beam downtimes.

2.3 SETUP

2.3.1 The COUPP apparatus will be delivered to Fermilab as a single unit.

2.3.2 Crane operators will be needed to lower the COUPP device into the MINOS hall.

2.3.3 Additional equipment (computers, miscellaneous equipment) amount to no more than one elevator trip.

2.3.4 There is no significant cabling involved in the COUPP apparatus.

2.3.5 A lifting device will be needed to raise the bubble chamber and set it on the bottom plates of its polyethylene shielding. Andrew Szymulanski of PPD/MD has identified a suitable lifting device (a small A-frame hoist)

2.4 SCHEDULE

2.4.1 We anticipate that the COUPP apparatus will be ready to come to Fermilab by late January, 2005.

2.4.2 Our run plan is included as Appendix III.

III. RESPONSIBILITIES BY INSTITUTION - NON FERMILAB

([] denotes replacement cost of existing hardware.)

3.1	Bubble chamber (inner vessel, pressure vessel, support frame, plumbing)	[$30k]
3.2	Digital cameras	[$5k]
3.3	(All equipment and DAQ will be supplied by the Kavli Institute group.)	
3.3.1	DAQ Computer and associated software and interfaces (LabView)	[$5k]
3.3.2	Digital Oscilloscope	[$5k]
3.3.3	Miscellaneous Lab Instrumentation (SRS Pre-amp, power supplies, etc)	[$3k]
	Total existing items	[$48k]

IV. RESPONSIBILITIES BY INSTITUTION - FERMILAB

([] Denotes replacement cost of existing hardware.)

4.1 Fermilab Accelerator Division:

4.1.1 We do not require Accelerator Division support.

4.1.S Summary of Accelerator Division costs:

Type of Funds	Equipment	Operating	Personnel (person-weeks)
Total new items	$0.0K	$0K	0.0

4.2 Fermilab Particle Physics Division

4.2.1 The PPD Mechanical Department will be responsible for the pressure vessel safety analysis of the bubble chamber outer vessel. This work has been largely completed by Andrew Szymulanski.

4.2.2 The PPD Mechanical Department will be responsible for analysis of the mechanical support issues for the chamber and its associated shielding. PPD/MD will be responsible for moving the equipment into the MINOS hall and for rigging and handling of the equipment into its final location.

4.2.3 The PPD Site Department will be responsible for site preparation which will primarily consist of the installation of a two 20-amp 110-Volt electrical receptacles near the apparatus.

4.2.4 The PPD ES&H Department will assist in all of the necessary safety reviews.

4.2.5 The PPD will coordinate access into the MINOS tunnel.

4.2.S Summary of Particle Physics Division costs:

Type of Funds	Equipment	Operating	Personnel (person-weeks)
Pressure Vessel Safety			4.0 engineer
Rigging, Support, Installation Analysis			2.0 engineer
Rigging and Installation		$4.0K	2.0 tech
Total new items	$0K	$4.0K	8.0

4.3 Fermilab Computing Division

4.3.1 An Ethernet connection to our Data Acquisition computer will be necessary.

4.3.2 PREP equipment will not be required.

Type of Funds	Equipment	Operating	Personnel (person-weeks)
Total existing items	[$0.0K]	$0K	0.0
Total new items	$1.0K	$0K	0.2

4.4 Fermilab ES&H Section

4.4.1 Assistance with safety reviews.

V. SUMMARY OF COSTS

Source of Funds [$K]	**Equipment**	**Operating**	**Personnel** (person-weeks)
Particle Physics Division	$0K	$4.0K	8
Accelerator Division	0	0	0
Computing Division	$1.0K	0	1
Totals Fermilab	$1.0K	$4.0K	9
Totals Non-Fermilab	[$48.0K]		

VI. SPECIAL CONSIDERATIONS

6.1 The responsibilities of the COUPP Spokesperson and procedures to be followed by experimenters are found in the Fermilab publication "Procedures for Experimenters" (PFX). The Physicist in charge agrees to those responsibilities and to follow the described procedures.

6.2 To carry out the experiment a number of Environmental, Safety and Health (ES&H) reviews are necessary. This includes creating a Partial Operational Readiness Clearance document in conjunction with the standing Particle Physics Division committee. The COUPP Spokesperson will follow those procedures in a timely manner, as well as any other requirements put forth by the division's safety officer.

6.3 All regulations concerning radioactive sources will be followed. No radioactive sources will be carried onto the site or moved without the approval of the Fermilab ES&H section.

6.4 All items in the Fermilab Policy on Computing will be followed by experimenters.

6.5 The COUPP Spokesperson will undertake to ensure that no PREP and computing equipment be transferred from the experiment to another use except with the approval of and through the mechanism provided by the Computing Division management. They also undertake to ensure that no modifications of PREP equipment take place without the knowledge and consent of the Computing Division management.

6.6 Each institution will be responsible for maintaining and repairing both the electronics and the computing hardware supplied by them for the experiment. Any items for which the experiment requests that Fermilab performs maintenance and repair should appear explicitly in this agreement.

6.7 If the experiment brings to Fermilab on-line data acquisition or data communications equipment to be integrated with Fermilab owned equipment, early consultation with the Computing Division is advised.

6.8 At the completion of the experiment:

6.8.1 The COUPP Spokesperson is responsible for the return of all PREP equipment, Computing equipment and non-PREP data acquisition electronics. If the return is not completed after a period of one year after the end of running the COUPP Spokesperson will be required to furnish, in writing, an explanation for any non-return.

6.8.2 The experimenters agree to remove their experimental equipment as the Laboratory requests them to. They agree to remove it expeditiously and in compliance with all ES&H requirements, including those related to transportation. All the expenses and personnel for the removal will be borne by the experimenters.

6.8.3 The experimenters will assist the Fermilab Divisions and Sections with the disposition of any articles left in the offices they occupied, including computer printout and magnetic tapes.

6.8.4 An experimenter will report on the test beam effort at a Fermilab All Experimenters Meeting.

SIGNATURES:

______________________________ / / 2005
Juan Collar (PI), Enrico Fermi Institute

____________________________________ / / 2005
Regina Rameika, MINOS group

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Jim Strait, Particle Physics Division

____________________________________ / / 2005
Roger Dixon, Accelerator Division

____________________________________ / / 2005
Victoria White, Computing Division

____________________________________ / / 2005
William Griffing, ES&H Section

_____________________________________ / /2005
Hugh Montgomery, Associate Director, Fermilab

_____________________________________ / /2005
Steven Holmes, Associate Director, Fermilab

APPENDIX I - Hazard Identification Checklist

Items for which there is anticipated need have been checked

Cryogenics		**Electrical Equipment**		**Hazardous/Toxic Materials**	
	Beam line magnets		Cryo/Electrical devices		List hazardous/toxic materials
	Analysis magnets		capacitor banks		planned for use in a beam line or experimental enclosure:
	Target		high voltage		
X*	(* our B.C. is *NOT* cryogenic) Bubble chamber		exposed equipment over 50 V		
Pressure Vessels		**Flammable Gases or Liquids**			
12 inches	inside diameter	Type:			
200 psi nom 600 psi rated	operating pressure	Flow rate:			
Glass	window material	Capacity:			
standard pressure rated glass windows	window thickness	**Radioactive Sources**			
Vacuum Vessels			permanent installation	**Target Materials**	
	inside diameter		temporary use		Beryllium (Be)
	operating pressure	Type:			Lithium (Li)
	window material	Strength:			Mercury (Hg)
	window thickness	**Hazardous Chemicals**			Lead (Pb)
Lasers			Cyanide plating materials		Tungsten (W)
	Permanent installation		Scintillation Oil		Uranium (U)
	Temporary installation		PCBs	**X**	Other : **CF3I, polypropylene glycol**
	Calibration		Methane	**Mechanical Structures**	
	Alignment		TMAE	**X**	Lifting devices
type:			TEA		Motion controllers
Wattage:			photographic developers		scaffolding/elevated platforms
class:			Other:		Others

APPENDIX II   LAYOUT OF THE COUPP TEST IN THE MINOS AREA.

Photo of the proposed site for the COUPP test in the MINOS enclosure.

APPENDIX III RUN PLAN.

1)	Rigging, installation, setup	1 week
2)	CF3I transfer, commissioning	1 week
3)	Data taking in unshielded configuration	2 weeks
4)	Addition of polyethylene shielding	1 week
5)	Data taking in shielded configuration	2 to 4 weeks